

## Fundamental Physical Constants — Extensive Listing

Quantity	Symbol	Value	Unit	Relative std. uncert. $u_r$
UNIVERSAL				
speed of light in vacuum	$c, c_0$	299 792 458	$\text{m s}^{-1}$	(exact)
magnetic constant	$\mu_0$	$4\pi \times 10^{-7}$	$\text{N A}^{-2}$	
		$= 12.566 370 614\dots \times 10^{-7}$	$\text{N A}^{-2}$	(exact)
electric constant $1/\mu_0 c^2$	$\epsilon_0$	$8.854 187 817\dots \times 10^{-12}$	$\text{F m}^{-1}$	(exact)
characteristic impedance of vacuum $\sqrt{\mu_0/\epsilon_0} = \mu_0 c$	$Z_0$	376.730 313 461...	$\Omega$	(exact)
Newtonian constant of gravitation	$G$	$6.6742(10) \times 10^{-11}$	$\text{m}^3 \text{kg}^{-1} \text{s}^{-2}$	$1.5 \times 10^{-4}$
	$G/\hbar c$	$6.7087(10) \times 10^{-39}$	$(\text{GeV}/c^2)^{-2}$	$1.5 \times 10^{-4}$
Planck constant in eV s	$h$	$6.626 0693(11) \times 10^{-34}$	$\text{J s}$	$1.7 \times 10^{-7}$
		$4.135 667 43(35) \times 10^{-15}$	$\text{eV s}$	$8.5 \times 10^{-8}$
$h/2\pi$ in eV s	$\hbar$	$1.054 571 68(18) \times 10^{-34}$	$\text{J s}$	$1.7 \times 10^{-7}$
		$6.582 119 15(56) \times 10^{-16}$	$\text{eV s}$	$8.5 \times 10^{-8}$
$\hbar c$ in MeV fm		197.326 968(17)	$\text{MeV fm}$	$8.5 \times 10^{-8}$
Planck mass $(\hbar c/G)^{1/2}$	$m_P$	$2.176 45(16) \times 10^{-8}$	kg	$7.5 \times 10^{-5}$
Planck temperature $(\hbar c^5/G)^{1/2}/k$	$T_P$	$1.416 79(11) \times 10^{32}$	K	$7.5 \times 10^{-5}$
Planck length $\hbar/m_P c = (\hbar G/c^3)^{1/2}$	$l_P$	$1.616 24(12) \times 10^{-35}$	m	$7.5 \times 10^{-5}$
Planck time $l_P/c = (\hbar G/c^5)^{1/2}$	$t_P$	$5.391 21(40) \times 10^{-44}$	s	$7.5 \times 10^{-5}$
ELECTROMAGNETIC				
elementary charge	$e$	$1.602 176 53(14) \times 10^{-19}$	C	$8.5 \times 10^{-8}$
	$e/h$	$2.417 989 40(21) \times 10^{14}$	$\text{A J}^{-1}$	$8.5 \times 10^{-8}$
magnetic flux quantum $h/2e$	$\Phi_0$	$2.067 833 72(18) \times 10^{-15}$	Wb	$8.5 \times 10^{-8}$
conductance quantum $2e^2/h$	$G_0$	$7.748 091 733(26) \times 10^{-5}$	S	$3.3 \times 10^{-9}$
inverse of conductance quantum	$G_0^{-1}$	12 906.403 725(43)	$\Omega$	$3.3 \times 10^{-9}$
Josephson constant <sup>1</sup> $2e/h$	$K_J$	$483 597.879(41) \times 10^9$	$\text{Hz V}^{-1}$	$8.5 \times 10^{-8}$
von Klitzing constant <sup>2</sup> $h/e^2 = \mu_0 c/2\alpha$	$R_K$	25 812.807 449(86)	$\Omega$	$3.3 \times 10^{-9}$
Bohr magneton $e\hbar/2m_e$ in eV T <sup>-1</sup>	$\mu_B$	$927.400 949(80) \times 10^{-26}$	$\text{J T}^{-1}$	$8.6 \times 10^{-8}$
		$5.788 381 804(39) \times 10^{-5}$	$\text{eV T}^{-1}$	$6.7 \times 10^{-9}$
	$\mu_B/h$	$13.996 2458(12) \times 10^9$	$\text{Hz T}^{-1}$	$8.6 \times 10^{-8}$
	$\mu_B/hc$	46.686 4507(40)	$\text{m}^{-1} \text{T}^{-1}$	$8.6 \times 10^{-8}$
	$\mu_B/k$	0.671 7131(12)	$\text{K T}^{-1}$	$1.8 \times 10^{-6}$
nuclear magneton $e\hbar/2m_p$ in eV T <sup>-1</sup>	$\mu_N$	$5.050 783 43(43) \times 10^{-27}$	$\text{J T}^{-1}$	$8.6 \times 10^{-8}$
		$3.152 451 259(21) \times 10^{-8}$	$\text{eV T}^{-1}$	$6.7 \times 10^{-9}$
	$\mu_N/h$	7.622 593 71(65)	$\text{MHz T}^{-1}$	$8.6 \times 10^{-8}$
	$\mu_N/hc$	$2.542 623 58(22) \times 10^{-2}$	$\text{m}^{-1} \text{T}^{-1}$	$8.6 \times 10^{-8}$
	$\mu_N/k$	$3.658 2637(64) \times 10^{-4}$	$\text{K T}^{-1}$	$1.8 \times 10^{-6}$
ATOMIC AND NUCLEAR General				

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Quantity	Symbol	Value	Unit	Relative std. uncert. $u_r$
fine-structure constant $e^2/4\pi\epsilon_0\hbar c$	$\alpha$	$7.297\,352\,568(24) \times 10^{-3}$		$3.3 \times 10^{-9}$
inverse fine-structure constant	$\alpha^{-1}$	$137.035\,999\,11(46)$		$3.3 \times 10^{-9}$
Rydberg constant $\alpha^2 m_e c / 2h$	$R_\infty$	$10\,973\,731.568\,525(73)$	$m^{-1}$	$6.6 \times 10^{-12}$
	$R_\infty c$	$3.289\,841\,960\,360(22) \times 10^{15}$	Hz	$6.6 \times 10^{-12}$
	$R_\infty hc$	$2.179\,872\,09(37) \times 10^{-18}$	J	$1.7 \times 10^{-7}$
$R_\infty hc$ in eV		$13.605\,6923(12)$	eV	$8.5 \times 10^{-8}$
Bohr radius $\alpha/4\pi R_\infty = 4\pi\epsilon_0\hbar^2/m_e e^2$	$a_0$	$0.529\,177\,2108(18) \times 10^{-10}$	m	$3.3 \times 10^{-9}$
Hartree energy $e^2/4\pi\epsilon_0 a_0 = 2R_\infty hc$ $= \alpha^2 m_e c^2$ in eV	$E_h$	$4.359\,744\,17(75) \times 10^{-18}$ $27.211\,3845(23)$	J eV	$1.7 \times 10^{-7}$ $8.5 \times 10^{-8}$
quantum of circulation	$h/2m_e$	$3.636\,947\,550(24) \times 10^{-4}$	$m^2 s^{-1}$	$6.7 \times 10^{-9}$
	$h/m_e$	$7.273\,895\,101(48) \times 10^{-4}$	$m^2 s^{-1}$	$6.7 \times 10^{-9}$
Electroweak				
Fermi coupling constant <sup>3</sup>	$G_F/(\hbar c)^3$	$1.166\,39(1) \times 10^{-5}$	$GeV^{-2}$	$8.6 \times 10^{-6}$
weak mixing angle <sup>4</sup> $\theta_W$ (on-shell scheme) $\sin^2 \theta_W = s_W^2 \equiv 1 - (m_W/m_Z)^2$	$\sin^2 \theta_W$	$0.222\,15(76)$		$3.4 \times 10^{-3}$
Electron, $e^-$				
electron mass in u, $m_e = A_r(e) u$ (electron relative atomic mass times u)	$m_e$	$9.109\,3826(16) \times 10^{-31}$	kg	$1.7 \times 10^{-7}$
energy equivalent in MeV	$m_e c^2$	$5.485\,799\,0945(24) \times 10^{-4}$ $8.187\,1047(14) \times 10^{-14}$ $0.510\,998\,918(44)$	u J MeV	$4.4 \times 10^{-10}$ $1.7 \times 10^{-7}$ $8.6 \times 10^{-8}$
electron-muon mass ratio	$m_e/m_\mu$	$4.836\,331\,67(13) \times 10^{-3}$		$2.6 \times 10^{-8}$
electron-tau mass ratio	$m_e/m_\tau$	$2.875\,64(47) \times 10^{-4}$		$1.6 \times 10^{-4}$
electron-proton mass ratio	$m_e/m_p$	$5.446\,170\,2173(25) \times 10^{-4}$		$4.6 \times 10^{-10}$
electron-neutron mass ratio	$m_e/m_n$	$5.438\,673\,4481(38) \times 10^{-4}$		$7.0 \times 10^{-10}$
electron-deuteron mass ratio	$m_e/m_d$	$2.724\,437\,1095(13) \times 10^{-4}$		$4.8 \times 10^{-10}$
electron to alpha particle mass ratio	$m_e/m_\alpha$	$1.370\,933\,555\,75(61) \times 10^{-4}$		$4.4 \times 10^{-10}$
electron charge to mass quotient	$-e/m_e$	$-1.758\,820\,12(15) \times 10^{11}$	$C\ kg^{-1}$	$8.6 \times 10^{-8}$
electron molar mass $N_A m_e$	$M(e), M_e$	$5.485\,799\,0945(24) \times 10^{-7}$	$kg\ mol^{-1}$	$4.4 \times 10^{-10}$
Compton wavelength $h/m_e c$ $\lambda_C/2\pi = \alpha a_0 = \alpha^2/4\pi R_\infty$	$\lambda_C$	$2.426\,310\,238(16) \times 10^{-12}$	m	$6.7 \times 10^{-9}$
classical electron radius $\alpha^2 a_0$	$\lambda_C$	$386.159\,2678(26) \times 10^{-15}$	m	$6.7 \times 10^{-9}$
Thomson cross section $(8\pi/3)r_e^2$	$r_e$	$2.817\,940\,325(28) \times 10^{-15}$	m	$1.0 \times 10^{-8}$
	$\sigma_e$	$0.665\,245\,873(13) \times 10^{-28}$	$m^2$	$2.0 \times 10^{-8}$
electron magnetic moment to Bohr magneton ratio	$\mu_e$	$-928.476\,412(80) \times 10^{-26}$	$J\ T^{-1}$	$8.6 \times 10^{-8}$
to nuclear magneton ratio	$\mu_e/\mu_B$	$-1.001\,159\,652\,1859(38)$		$3.8 \times 10^{-12}$
electron magnetic moment anomaly $ \mu_e /\mu_B - 1$	$\mu_e/\mu_N$	$-1838.281\,971\,07(85)$		$4.6 \times 10^{-10}$
	$a_e$	$1.159\,652\,1859(38) \times 10^{-3}$		$3.2 \times 10^{-9}$
electron g-factor $-2(1 + a_e)$	$g_e$	$-2.002\,319\,304\,3718(75)$		$3.8 \times 10^{-12}$

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electron-muon magnetic moment ratio	$\mu_e/\mu_\mu$	206.766 9894(54)		$2.6 \times 10^{-8}$
electron-proton magnetic moment ratio	$\mu_e/\mu_p$	-658.210 6862(66)		$1.0 \times 10^{-8}$
electron to shielded proton magnetic moment ratio (H <sub>2</sub> O, sphere, 25 °C)	$\mu_e/\mu'_p$	-658.227 5956(71)		$1.1 \times 10^{-8}$
electron-neutron magnetic moment ratio	$\mu_e/\mu_n$	960.920 50(23)		$2.4 \times 10^{-7}$
electron-deuteron magnetic moment ratio	$\mu_e/\mu_d$	-2143.923 493(23)		$1.1 \times 10^{-8}$
electron to shielded helion <sup>5</sup> magnetic moment ratio (gas, sphere, 25 °C)	$\mu_e/\mu'_h$	864.058 255(10)		$1.2 \times 10^{-8}$
electron gyromagnetic ratio $2 \mu_e /\hbar$	$\gamma_e$	$1.760\,859\,74(15) \times 10^{11}$	$s^{-1} T^{-1}$	$8.6 \times 10^{-8}$
	$\gamma_e/2\pi$	28 024.9532(24)	MHz T <sup>-1</sup>	$8.6 \times 10^{-8}$
		Muon, $\mu^-$		
muon mass in u, $m_\mu = A_r(\mu)$ u (muon relative atomic mass times u)	$m_\mu$	$1.883\,531\,40(33) \times 10^{-28}$	kg	$1.7 \times 10^{-7}$
energy equivalent in MeV	$m_\mu c^2$	0.113 428 9264(30) $1.692\,833\,60(29) \times 10^{-11}$ 105.658 3692(94)	u J MeV	$2.6 \times 10^{-8}$ $1.7 \times 10^{-7}$ $8.9 \times 10^{-8}$
muon-electron mass ratio	$m_\mu/m_e$	206.768 2838(54)		$2.6 \times 10^{-8}$
muon-tau mass ratio	$m_\mu/m_\tau$	$5.945\,92(97) \times 10^{-2}$		$1.6 \times 10^{-4}$
muon-proton mass ratio	$m_\mu/m_p$	0.112 609 5269(29)		$2.6 \times 10^{-8}$
muon-neutron mass ratio	$m_\mu/m_n$	0.112 454 5175(29)		$2.6 \times 10^{-8}$
muon molar mass $N_A m_\mu$	$M(\mu), M_\mu$	$0.113\,428\,9264(30) \times 10^{-3}$	kg mol <sup>-1</sup>	$2.6 \times 10^{-8}$
muon Compton wavelength $h/m_\mu c$	$\lambda_{C,\mu}$	$11.734\,441\,05(30) \times 10^{-15}$	m	$2.5 \times 10^{-8}$
	$\lambda_{C,\mu}/2\pi$	$1.867\,594\,298(47) \times 10^{-15}$	m	$2.5 \times 10^{-8}$
muon magnetic moment to Bohr magneton ratio	$\mu_\mu/\mu_B$	$-4.490\,447\,99(40) \times 10^{-26}$	J T <sup>-1</sup>	$8.9 \times 10^{-8}$
to nuclear magneton ratio	$\mu_\mu/\mu_N$	$-4.841\,970\,45(13) \times 10^{-3}$		$2.6 \times 10^{-8}$
		-8.890 596 98(23)		$2.6 \times 10^{-8}$
muon magnetic moment anomaly $ \mu_\mu /(e\hbar/2m_\mu) - 1$	$a_\mu$	$1.165\,919\,81(62) \times 10^{-3}$		$5.3 \times 10^{-7}$
muon g-factor $-2(1 + a_\mu)$	$g_\mu$	-2.002 331 8396(12)		$6.2 \times 10^{-10}$
muon-proton magnetic moment ratio	$\mu_\mu/\mu_p$	-3.183 345 118(89)		$2.8 \times 10^{-8}$
		Tau, $\tau^-$		
tau mass <sup>6</sup> in u, $m_\tau = A_r(\tau)$ u (tau relative atomic mass times u)	$m_\tau$	$3.167\,77(52) \times 10^{-27}$	kg	$1.6 \times 10^{-4}$
energy equivalent	$m_\tau c^2$	1.907 68(31) $2.847\,05(46) \times 10^{-10}$	u J	$1.6 \times 10^{-4}$ $1.6 \times 10^{-4}$

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Quantity	Symbol	Value	Unit	Relative std. uncert. $u_r$
in MeV		1776.99(29)	MeV	$1.6 \times 10^{-4}$
tau-electron mass ratio	$m_\tau/m_e$	3477.48(57)		$1.6 \times 10^{-4}$
tau-muon mass ratio	$m_\tau/m_\mu$	16.8183(27)		$1.6 \times 10^{-4}$
tau-proton mass ratio	$m_\tau/m_p$	1.893 90(31)		$1.6 \times 10^{-4}$
tau-neutron mass ratio	$m_\tau/m_n$	1.891 29(31)		$1.6 \times 10^{-4}$
tau molar mass $N_A m_\tau$	$M(\tau), M_\tau$	$1.907\,68(31) \times 10^{-3}$	$\text{kg mol}^{-1}$	$1.6 \times 10^{-4}$
tau Compton wavelength $h/m_\tau c$	$\lambda_{C,\tau}$	$0.697\,72(11) \times 10^{-15}$	m	$1.6 \times 10^{-4}$
$\lambda_{C,\tau}/2\pi$	$\tilde{\lambda}_{C,\tau}$	$0.111\,046(18) \times 10^{-15}$	m	$1.6 \times 10^{-4}$
Proton, p				
proton mass in u, $m_p = A_r(p)$ u (proton relative atomic mass times u)	$m_p$	$1.672\,621\,71(29) \times 10^{-27}$	kg	$1.7 \times 10^{-7}$
energy equivalent in MeV	$m_p c^2$	1.007 276 466 88(13) $1.503\,277\,43(26) \times 10^{-10}$ 938.272 029(80)	u J MeV	$1.3 \times 10^{-10}$ $1.7 \times 10^{-7}$ $8.6 \times 10^{-8}$
proton-electron mass ratio	$m_p/m_e$	1836.152 672 61(85)		$4.6 \times 10^{-10}$
proton-muon mass ratio	$m_p/m_\mu$	8.880 243 33(23)		$2.6 \times 10^{-8}$
proton-tau mass ratio	$m_p/m_\tau$	0.528 012(86)		$1.6 \times 10^{-4}$
proton-neutron mass ratio	$m_p/m_n$	0.998 623 478 72(58)		$5.8 \times 10^{-10}$
proton charge to mass quotient	$e/m_p$	$9.578\,833\,76(82) \times 10^7$	$C\ kg^{-1}$	$8.6 \times 10^{-8}$
proton molar mass $N_A m_p$	$M(p), M_p$	$1.007\,276\,466\,88(13) \times 10^{-3}$	$\text{kg mol}^{-1}$	$1.3 \times 10^{-10}$
proton Compton wavelength $h/m_p c$	$\lambda_{C,p}$	$1.321\,409\,8555(88) \times 10^{-15}$	m	$6.7 \times 10^{-9}$
$\lambda_{C,p}/2\pi$	$\tilde{\lambda}_{C,p}$	$0.210\,308\,9104(14) \times 10^{-15}$	m	$6.7 \times 10^{-9}$
proton rms charge radius	$R_p$	$0.8750(68) \times 10^{-15}$	m	$7.8 \times 10^{-3}$
proton magnetic moment to Bohr magneton ratio	$\mu_p$	$1.410\,606\,71(12) \times 10^{-26}$	$J\ T^{-1}$	$8.7 \times 10^{-8}$
to nuclear magneton ratio	$\mu_p/\mu_B$	$1.521\,032\,206(15) \times 10^{-3}$		$1.0 \times 10^{-8}$
	$\mu_p/\mu_N$	2.792 847 351(28)		$1.0 \times 10^{-8}$
proton g-factor $2\mu_p/\mu_N$	$g_p$	5.585 694 701(56)		$1.0 \times 10^{-8}$
proton-neutron magnetic moment ratio	$\mu_p/\mu_n$	-1.459 898 05(34)		$2.4 \times 10^{-7}$
shielded proton magnetic moment (H <sub>2</sub> O, sphere, 25 °C)	$\mu'_p$	$1.410\,570\,47(12) \times 10^{-26}$	$J\ T^{-1}$	$8.7 \times 10^{-8}$
to Bohr magneton ratio	$\mu'_p/\mu_B$	$1.520\,993\,132(16) \times 10^{-3}$		$1.1 \times 10^{-8}$
to nuclear magneton ratio	$\mu'_p/\mu_N$	2.792 775 604(30)		$1.1 \times 10^{-8}$
proton magnetic shielding correction $1 - \mu'_p/\mu_p$ (H <sub>2</sub> O, sphere, 25 °C)	$\sigma'_p$	$25.689(15) \times 10^{-6}$		$5.7 \times 10^{-4}$
proton gyromagnetic ratio $2\mu_p/\hbar$	$\gamma_p$	$2.675\,222\,05(23) \times 10^8$	$s^{-1}\ T^{-1}$	$8.6 \times 10^{-8}$
	$\gamma_p/2\pi$	42.577 4813(37)	$\text{MHz}\ T^{-1}$	$8.6 \times 10^{-8}$
shielded proton gyromagnetic ratio $2\mu'_p/\hbar$ (H <sub>2</sub> O, sphere, 25 °C)	$\gamma'_p$	$2.675\,153\,33(23) \times 10^8$	$s^{-1}\ T^{-1}$	$8.6 \times 10^{-8}$

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	$\gamma'_p/2\pi$	42.576 3875(37)	MHz T <sup>-1</sup>	$8.6 \times 10^{-8}$
Neutron, n				
neutron mass in u, $m_n = A_r(n) u$ (neutron relative atomic mass times u)	$m_n$	$1.674\,927\,28(29) \times 10^{-27}$	kg	$1.7 \times 10^{-7}$
energy equivalent in MeV	$m_n c^2$	1.008 664 915 60(55) $1.505\,349\,57(26) \times 10^{-10}$ 939.565 360(81)	u J MeV	$5.5 \times 10^{-10}$ $1.7 \times 10^{-7}$ $8.6 \times 10^{-8}$
neutron-electron mass ratio	$m_n/m_e$	1838.683 6598(13)		$7.0 \times 10^{-10}$
neutron-muon mass ratio	$m_n/m_\mu$	8.892 484 02(23)		$2.6 \times 10^{-8}$
neutron-tau mass ratio	$m_n/m_\tau$	0.528 740(86)		$1.6 \times 10^{-4}$
neutron-proton mass ratio	$m_n/m_p$	1.001 378 418 70(58)		$5.8 \times 10^{-10}$
neutron molar mass $N_A m_n$	$M(n), M_n$	$1.008\,664\,915\,60(55) \times 10^{-3}$	kg mol <sup>-1</sup>	$5.5 \times 10^{-10}$
neutron Compton wavelength $h/m_n c$ $\lambda_{C,n}/2\pi$	$\lambda_{C,n}$	$1.319\,590\,9067(88) \times 10^{-15}$	m	$6.7 \times 10^{-9}$
neutron magnetic moment to Bohr magneton ratio	$\mu_n$	$0.210\,019\,4157(14) \times 10^{-15}$	m	$6.7 \times 10^{-9}$
to nuclear magneton ratio	$\mu_n/\mu_N$	$-0.966\,236\,45(24) \times 10^{-26}$	J T <sup>-1</sup>	$2.5 \times 10^{-7}$
neutron g-factor $2\mu_n/\mu_N$	$g_n$	-3.826 085 46(90)		$2.4 \times 10^{-7}$
neutron-electron magnetic moment ratio	$\mu_n/\mu_e$	1.040 668 82(25) × 10 <sup>-3</sup>		$2.4 \times 10^{-7}$
neutron-proton magnetic moment ratio	$\mu_n/\mu_p$	-0.684 979 34(16)		$2.4 \times 10^{-7}$
neutron to shielded proton magnetic moment ratio (H <sub>2</sub> O, sphere, 25 °C)	$\mu_n/\mu'_p$	-0.684 996 94(16)		$2.4 \times 10^{-7}$
neutron gyromagnetic ratio $2 \mu_n /\hbar$	$\gamma_n$	1.832 471 83(46) × 10 <sup>8</sup>	s <sup>-1</sup> T <sup>-1</sup>	$2.5 \times 10^{-7}$
	$\gamma_n/2\pi$	29.164 6950(73)	MHz T <sup>-1</sup>	$2.5 \times 10^{-7}$
Deuteron, d				
deuteron mass in u, $m_d = A_r(d) u$ (deuteron relative atomic mass times u)	$m_d$	$3.343\,583\,35(57) \times 10^{-27}$	kg	$1.7 \times 10^{-7}$
energy equivalent in MeV	$m_d c^2$	2.013 553 212 70(35) $3.005\,062\,85(51) \times 10^{-10}$ 1875.612 82(16)	u J MeV	$1.7 \times 10^{-10}$ $1.7 \times 10^{-7}$ $8.6 \times 10^{-8}$
deuteron-electron mass ratio	$m_d/m_e$	3670.482 9652(18)		$4.8 \times 10^{-10}$
deuteron-proton mass ratio	$m_d/m_p$	1.999 007 500 82(41)		$2.0 \times 10^{-10}$
deuteron molar mass $N_A m_d$	$M(d), M_d$	$2.013\,553\,212\,70(35) \times 10^{-3}$	kg mol <sup>-1</sup>	$1.7 \times 10^{-10}$
deuteron rms charge radius	$R_d$	$2.1394(28) \times 10^{-15}$	m	$1.3 \times 10^{-3}$
deuteron magnetic moment to Bohr magneton ratio	$\mu_d$	$0.433\,073\,482(38) \times 10^{-26}$	J T <sup>-1</sup>	$8.7 \times 10^{-8}$
to nuclear magneton ratio	$\mu_d/\mu_N$	$0.466\,975\,4567(50) \times 10^{-3}$		$1.1 \times 10^{-8}$
		0.857 438 2329(92)		$1.1 \times 10^{-8}$

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deuteron-electron magnetic moment ratio	$\mu_d/\mu_e$	$-4.664\,345\,548(50) \times 10^{-4}$		$1.1 \times 10^{-8}$
deuteron-proton magnetic moment ratio	$\mu_d/\mu_p$	$0.307\,012\,2084(45)$		$1.5 \times 10^{-8}$
deuteron-neutron magnetic moment ratio	$\mu_d/\mu_n$	$-0.448\,206\,52(11)$		$2.4 \times 10^{-7}$
Helion, h				
helion mass <sup>5</sup> in u, $m_h = A_r(h)$ u (helion relative atomic mass times u)	$m_h$	$5.006\,412\,14(86) \times 10^{-27}$	kg	$1.7 \times 10^{-7}$
energy equivalent in MeV	$m_h c^2$	$3.014\,932\,2434(58)$ $4.499\,538\,84(77) \times 10^{-10}$ $2808.391\,42(24)$	u J MeV	$1.9 \times 10^{-9}$ $1.7 \times 10^{-7}$ $8.6 \times 10^{-8}$
helion-electron mass ratio	$m_h/m_e$	$5495.885\,269(11)$		$2.0 \times 10^{-9}$
helion-proton mass ratio	$m_h/m_p$	$2.993\,152\,6671(58)$		$1.9 \times 10^{-9}$
helion molar mass $N_A m_h$	$M(h), M_h$	$3.014\,932\,2434(58) \times 10^{-3}$	kg mol <sup>-1</sup>	$1.9 \times 10^{-9}$
shielded helion magnetic moment (gas, sphere, 25 °C)	$\mu'_h$	$-1.074\,553\,024(93) \times 10^{-26}$	J T <sup>-1</sup>	$8.7 \times 10^{-8}$
to Bohr magneton ratio	$\mu'_h/\mu_B$	$-1.158\,671\,474(14) \times 10^{-3}$		$1.2 \times 10^{-8}$
to nuclear magneton ratio	$\mu'_h/\mu_N$	$-2.127\,497\,723(25)$		$1.2 \times 10^{-8}$
shielded helion to proton magnetic moment ratio (gas, sphere, 25 °C)	$\mu'_h/\mu_p$	$-0.761\,766\,562(12)$		$1.5 \times 10^{-8}$
shielded helion to shielded proton magnetic moment ratio (gas/H <sub>2</sub> O, spheres, 25 °C)	$\mu'_h/\mu'_p$	$-0.761\,786\,1313(33)$		$4.3 \times 10^{-9}$
shielded helion gyromagnetic ratio $2 \mu'_h /\hbar$ (gas, sphere, 25 °C)	$\gamma'_h$	$2.037\,894\,70(18) \times 10^8$	s <sup>-1</sup> T <sup>-1</sup>	$8.7 \times 10^{-8}$
	$\gamma'_h/2\pi$	$32.434\,1015(28)$	MHz T <sup>-1</sup>	$8.7 \times 10^{-8}$
Alpha particle, $\alpha$				
alpha particle mass in u, $m_\alpha = A_r(\alpha)$ u (alpha particle relative atomic mass times u)	$m_\alpha$	$6.644\,6565(11) \times 10^{-27}$	kg	$1.7 \times 10^{-7}$
energy equivalent in MeV	$m_\alpha c^2$	$4.001\,506\,179\,149(56)$ $5.971\,9194(10) \times 10^{-10}$ $3727.379\,17(32)$	u J MeV	$1.4 \times 10^{-11}$ $1.7 \times 10^{-7}$ $8.6 \times 10^{-8}$
alpha particle to electron mass ratio	$m_\alpha/m_e$	$7294.299\,5363(32)$		$4.4 \times 10^{-10}$
alpha particle to proton mass ratio	$m_\alpha/m_p$	$3.972\,599\,689\,07(52)$		$1.3 \times 10^{-10}$
alpha particle molar mass $N_A m_\alpha$	$M(\alpha), M_\alpha$	$4.001\,506\,179\,149(56) \times 10^{-3}$	kg mol <sup>-1</sup>	$1.4 \times 10^{-11}$
PHYSICO-CHEMICAL				
Avogadro constant	$N_A, L$	$6.022\,1415(10) \times 10^{23}$	mol <sup>-1</sup>	$1.7 \times 10^{-7}$
atomic mass constant $m_u = \frac{1}{12}m(^{12}\text{C}) = 1$ u	$m_u$	$1.660\,538\,86(28) \times 10^{-27}$	kg	$1.7 \times 10^{-7}$

## Fundamental Physical Constants — Extensive Listing

Quantity	Symbol	Value	Unit	Relative std. uncert. $u_r$
$= 10^{-3} \text{ kg mol}^{-1}/N_A$ energy equivalent in MeV	$m_u c^2$	$1.492\,417\,90(26) \times 10^{-10}$ $931.494\,043(80)$	J MeV	$1.7 \times 10^{-7}$ $8.6 \times 10^{-8}$
Faraday constant <sup>7</sup> $N_A e$	$F$	96 485.3383(83)	C mol <sup>-1</sup>	$8.6 \times 10^{-8}$
molar Planck constant	$N_A h$	$3.990\,312\,716(27) \times 10^{-10}$	J s mol <sup>-1</sup>	$6.7 \times 10^{-9}$
molar gas constant	$N_A h c$	0.119 626 565 72(80)	J m mol <sup>-1</sup>	$6.7 \times 10^{-9}$
Boltzmann constant $R/N_A$ in eV K <sup>-1</sup>	$R$	8.314 472(15)	J mol <sup>-1</sup> K <sup>-1</sup>	$1.7 \times 10^{-6}$
	$k$	$1.380\,6505(24) \times 10^{-23}$ $8.617\,343(15) \times 10^{-5}$	J K <sup>-1</sup> eV K <sup>-1</sup>	$1.8 \times 10^{-6}$ $1.8 \times 10^{-6}$
	$k/h$	$2.083\,6644(36) \times 10^{10}$	Hz K <sup>-1</sup>	$1.7 \times 10^{-6}$
	$k/hc$	69.503 56(12)	m <sup>-1</sup> K <sup>-1</sup>	$1.7 \times 10^{-6}$
molar volume of ideal gas $RT/p$ $T = 273.15 \text{ K}, p = 101.325 \text{ kPa}$	$V_m$	$22.413\,996(39) \times 10^{-3}$	m <sup>3</sup> mol <sup>-1</sup>	$1.7 \times 10^{-6}$
Loschmidt constant $N_A/V_m$	$n_0$	2.686 7773(47) × 10 <sup>25</sup>	m <sup>-3</sup>	$1.8 \times 10^{-6}$
$T = 273.15 \text{ K}, p = 100 \text{ kPa}$	$V_m$	22.710 981(40) × 10 <sup>-3</sup>	m <sup>3</sup> mol <sup>-1</sup>	$1.7 \times 10^{-6}$
Sackur-Tetrode constant (absolute entropy constant) <sup>8</sup> $\frac{5}{2} + \ln[(2\pi m_u k T_1/h^2)^{3/2} k T_1/p_0]$ $T_1 = 1 \text{ K}, p_0 = 100 \text{ kPa}$ $T_1 = 1 \text{ K}, p_0 = 101.325 \text{ kPa}$	$S_0/R$	$-1.151\,7047(44)$ $-1.164\,8677(44)$		$3.8 \times 10^{-6}$ $3.8 \times 10^{-6}$
Stefan-Boltzmann constant ( $\pi^2/60$ ) $k^4/\hbar^3 c^2$	$\sigma$	$5.670\,400(40) \times 10^{-8}$	W m <sup>-2</sup> K <sup>-4</sup>	$7.0 \times 10^{-6}$
first radiation constant $2\pi hc^2$	$c_1$	$3.741\,771\,38(64) \times 10^{-16}$	W m <sup>2</sup>	$1.7 \times 10^{-7}$
first radiation constant for spectral radiance $2hc^2$	$c_{1L}$	$1.191\,042\,82(20) \times 10^{-16}$	W m <sup>2</sup> sr <sup>-1</sup>	$1.7 \times 10^{-7}$
second radiation constant $hc/k$	$c_2$	$1.438\,7752(25) \times 10^{-2}$	m K	$1.7 \times 10^{-6}$
Wien displacement law constant $b = \lambda_{\max} T = c_2/4.965\,114\,231\dots$	$b$	$2.897\,7685(51) \times 10^{-3}$	m K	$1.7 \times 10^{-6}$

<sup>1</sup> See the “Adopted values” table for the conventional value adopted internationally for realizing representations of the volt using the Josephson effect.

<sup>2</sup> See the “Adopted values” table for the conventional value adopted internationally for realizing representations of the ohm using the quantum Hall effect.

<sup>3</sup> Value recommended by the Particle Data Group (Hagiwara, *et al.*, 2002).

<sup>4</sup> Based on the ratio of the masses of the W and Z bosons  $m_W/m_Z$  recommended by the Particle Data Group (Hagiwara, *et al.*, 2002). The value for  $\sin^2\theta_W$  they recommend, which is based on a particular variant of the modified minimal subtraction ( $\overline{\text{MS}}$ ) scheme, is  $\sin^2\hat{\theta}_W(M_Z) = 0.231\,24(24)$ .

<sup>5</sup> The helion, symbol h, is the nucleus of the  $^3\text{He}$  atom.

<sup>6</sup> This and all other values involving  $m_\tau$  are based on the value of  $m_\tau c^2$  in MeV recommended by the Particle Data Group, (Hagiwara, *et al.*, 2002), but with a standard uncertainty of 0.29 MeV rather than the quoted uncertainty of  $-0.26 \text{ MeV}, +0.29 \text{ MeV}$ .

<sup>7</sup> The numerical value of  $F$  to be used in coulometric chemical measurements is 96 485.336(16) [ $1.7 \times 10^{-7}$ ] when the relevant current is measured in terms of representations of the volt and ohm based on the Josephson and quantum Hall effects and the internationally adopted conventional values of the Josephson and von Klitzing constants  $K_{\text{J}-90}$  and  $R_{\text{K}-90}$  given in the “Adopted values” table.

<sup>8</sup> The entropy of an ideal monoatomic gas of relative atomic mass  $A_r$  is given by  $S = S_0 + \frac{3}{2}R \ln A_r - R \ln(p/p_0) + \frac{5}{2}R \ln(T/K)$ . <sup>9</sup> The relative atomic mass  $A_r(X)$  of particle X with mass  $m(X)$  is defined by  $A_r(X) = m(X)/m_u$ , where  $m_u = m(^{12}\text{C})/12 = M_u/N_A = 1 \text{ u}$  is the atomic mass constant,  $N_A$  is the Avogadro constant, and u is the atomic mass unit. Thus the mass of particle X in u is  $m(X) = A_r(X) u$  and the molar mass of X is  $M(X) = A_r(X) M_u$ .

<sup>10</sup> This is the value adopted internationally for realizing representations of the volt using the Josephson effect.

<sup>11</sup> This is the value adopted internationally for realizing representations of the ohm using the quantum Hall effect. <sup>a</sup> This is the lattice parameter (unit cell edge length) of an ideal single crystal of naturally occurring Si free of impurities and imperfections, and is deduced from measurements on extremely pure and nearly perfect single crystals of Si by correcting for the effects of impurities.